The High Performance Computing Environment (Grid) in China

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1. Introduction

The rapid development of Internet and high performance computing technology has stimulated the research on the new information infrastructure, the Grid. Researches on Grid technology are being carried out in a number of countries. A prototype Grid system, the National High Performance Computing Environment, has been developed in China with the support from the National High-tech Research and Development Program (the 863 program). This paper is going to give an overview of this project, on its motivation, the major research activities involved, and the prospects of the project. Section 2 will discuss the purpose of developing a Grid system and give a comparison between the current Internet and the Grid. The project objective and research tasks will be outlined in section 3. The key issues in developing a Grid system are addressed in section 4. The current status of the project and further development are discussed in section 5. This paper does not attempt to cover technical details of the project. Its purpose is to show China’s research effort on Grid and to pursue the possible international cooperation in this field.

2. The purpose of developing a Grid in China

A Grid, or sometimes called a meta-computing system, is a new form of information infrastructure. Physically, a Grid is composed of remotely distributed heterogeneous resources connected by networks. The resources include high performance computers, network servers, mass storage devices, expensive instruments, databases, software tools, varies application software, etc. The Grid hides the heterogeneity of the under-layer individual components from the end user. It presents itself as a single powerful super computer with the tremendous computing and storage capability. People usually use the power supply network as an analogue to the Grid. Just as we use electricity daily without concerning where the electricity comes from, the users of the future Grid simply send out their requests for service and information to the Grid and then receive the desired result. They will not care how and where their requests are satisfied.

The Grid defers from the current Internet and Web in several aspects. First, as mentioned above, the Grid provides a single system image to the end user, while the Internet, or Web, is composed of distributed resources that users have to find out and explicitly exploit by their own effort. Secondly, the Grid enables and encourages resource sharing and collaboration, while the resource sharing and collaboration among Internet users requires carefully designed protocols and sophisticated control mechanism. Thirdly, the resources, users, and tasks are managed and scheduled uniformly in the Grid. However, in the Internet, there is no global and uniform management and control at all. Finally, the Grid will have certain intelligence in assisting users to obtain useful information and knowledge, while the current Internet behaves just as a huge a reservoir full of massive information, but the useful information has to be separated from garbage.
by user’s own effort.

China is experiencing a rapid development. We are living in a transition to the modern information era. The needs for communication and collaboration, the desire for fresh information and knowledge, and the demands to computing power have never been such great. We can easily list a number of applications that require super computer capability: long-term precise weather forecast, rapid crises response, prediction of social and economical development by simulation, new synthetic medicine design with molecular level simulation, environment monitoring, etc. But the existing situation is that a large number of computers are infrequently used or even sit there idly; information is isolated in the so-called information island and difficult to share, expensive software and instruments are underused. The Grid will be a necessity to change the situation.

Based on the above observation, the 863 program initiated a key project named National High Performance Computing Environment, or simply called CNGRID. The purpose of this project is to establish a prototype Grid system to carry out experiment on information infrastructure for the future society. Its mission will be twofold: providing aggregative super computing power and enabling the usage of idle computing resources. It will not only deliver the super computing power to the desk of scientists and engineers, but also enable super computer applications such as high quality information services to the ordinary people. The project was initiated in 1999 and has completed its first stage of development by the end of the year 2000. In the following section, I will give an overview of the project.

3. Overview of the CNGRID project

The project is composed of the following four tasks:

1) Develop a high performance computer. It should be scalable and can be used as the main computing power in the Grid environment;

2) Establish several high performance computing centers across the country. These centers are interconnected via dedicated or public networks to form the physical platform of the Grid environment.

3) Develop a system software for the Grid to provide Grid-specific functions.

4) Develop several typical applications in the Grid environment to demonstrate the feasibility and performance of the prototype system.

More than 20 sub-projects were planned and supported to fulfill the above tasks. Several hundred researchers were involved in the research and development. The project continued for two years and a prototype system had been put into operation by the end of the year 2000.

4. Major issues in developing a Grid system

Several issues have to be addressed in developing a Grid system.

**Heterogeneity.** The Grid is composed of heterogeneous resources distributed in separate management domains across the wide area network, differences in hardware platforms, data formats, operating systems, or even compiler versions, will make interoperability a problem. The Grid must conceal the heterogeneity from the end user and perform necessary conversion automatically.

**Scalability.** The Grid system must keep its performance proportional to its scale while resources and applications are constantly added or removed.

**Dynamic adaptation.** The Grid itself changes dynamically due to the availability of the
resources, the failure of individual resource, or fluctuation of the traffic in the network. It must be able to monitor the status of its resources and select the best way to provide services.

Safety. Safety in user program execution and protection of user private data must be guaranteed while resource sharing is globally supported.

Some key technologies must be studied in addressing the above issues.

Uniform management of resources. All resources in the Grid must be managed uniformly to provide a uniform system image.

Uniform user management. All users must be managed uniformly so that each user has a unique identification and account.

Efficient task scheduling. The Grid schedules tasks dynamically based on monitoring of its resources to deliver the best performance. The optimal task scheduling in an environment with high latency will be a challenge.

Grid Security. Authorization, authentication, and encryption must be used to enhance Grid security. Secure operating system at the grid node is also the basis of the Grid security.

User-friendly interface. Graphical user interface is essential for improving the user-system interface. A Web-based user interface is expected to reduce the effort in installing client-side software. The Web-based interface also simplifies the software upgrading process.

5. Current status of the project and the future work

As a major task of the project mentioned in section 3, the Dawning 3000 super server was developed by the National Intelligent Computer R&D center. It consists of 280 processors organized into 70 quad-processor nodes, 160GB main memory, 3TB hard disks, and high speed inter-connection networks (using both worm-hole routers and SAN switches). The peak performance of the system is 0.4TFlops. Dawning 3000 adopts a scalable architecture. Systems of different scales can be configured to meet the requirement of a wide range of applications. The principle of SUMA (Scalability, Usability, Maintainability, and Availability) is emphasized and practiced to improve the overall system performance. Several Dawning computers with different configurations were delivered and installed in the high-performance centers.

Eight high-performance computing centers were established. The locations of the centers include Beijing (north), Shanghai (east-south), Xian (northwest), Hefei (east-north), Wuhan (central), Changsha (central-south), and Chengdu (southwest), covering important areas of the country. Each node is equipped with a computer whose speed ranges from 10 GFlops to 100 GFlops. These centers are interconnected by the existing networks such as CSTNet and Cernet, forming the physical platform of the Grid. Domestically developed computers including Dawning computers, Yin He computers, and Sunway computers are installed in these centers.

A set of system software for Grid was developed by a joint team with researchers coming from several research institutes and universities. The software provides a layer of functions above the node operating system. It supports uniform management and scheduling to all resources, users, and jobs in the environment. The security issue is addressed by special encrypt/decrypt hardware as well as software solutions such as authentication. Web-based software technology is adopted to achieve good portability and reduce the effort in client-side software installation.

Several applications were carefully selected and developed in the Grid. The applications include weather forecasting system, petroleum reservoir simulation, bio-information system, numerical wind tunnel, ship structure analysis, car crashing simulation, scientific databases, and
digital library. They cover both scientific/engineering computation and data-intensive information services. By the end of the year 2000, these applications had been in function.

As a continuing effort in developing the Grid technology in China, the 863 program in the national tenth five-year plan places the research on Grid in an important position. A key project for continual development of CNGRID has been proposed and approved. The research effort will be focused on the following aspects:

- Theoretical models of the Grid environment;
- Grid architectures;
- Efficient communication protocols;
- Grid operating systems;
- Grid application development tools;
- User-friendly interfaces;
- Killer applications in Grid;
- Grid performance evaluation and optimization;

Among the research tasks, we believe that developing the killer Grid applications is most important. It is the application that can stimulate the research and establish the faith to the new technology.

6. Conclusion

As an important composition part of the worldwide efforts in developing the Grid system, the practice of developing CNGRID has shown its significance and attracted attention of international academia. A new project supporting further research in this direction has been approved and is to be started soon. The progress and experiences in Grid technology in other countries, especially in European countries, will be extremely valuable and beneficial to our further research in the new project. International cooperation is strongly encouraged in carrying out the new project. We are looking forward to the effective cooperation with international colleagues.